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1. Your reference — P/63675.GBA/VISD

2. Patent application number *(The Patent Office will fill in this part)* — 0225995.0 — 7 NOV 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

E2V Technologies Limited
106 Waterhouse Lane
Chelmsford
Essex
CM1 2QU

Patents ADP number *(if you know it)* 8457749001

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom — IE

4. Title of the invention — GAS SENSORS

5. Name of your agent *(if you have one)* — N. Hucker — REDDIE + GROSE 16, THEOBALDS ROAD LONDON WC1X 8PL

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Marconi Intellectual Property
Marrable House
The Vineyards
Great Baddow
Chelmsford
Essex CM2 7DS

Patents ADP number *(if you know it)* 8225245001 — IE

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Country	Priority application number *(if you know)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

YES

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Claim(s)	4
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Priority documents	(0)
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Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	(0)
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Nerys Hucker Date 07/11/02

12. Name and daytime telephone number of person to contact in the United Kingdom

Nerys Hucker
01245 493 493 ext.3122

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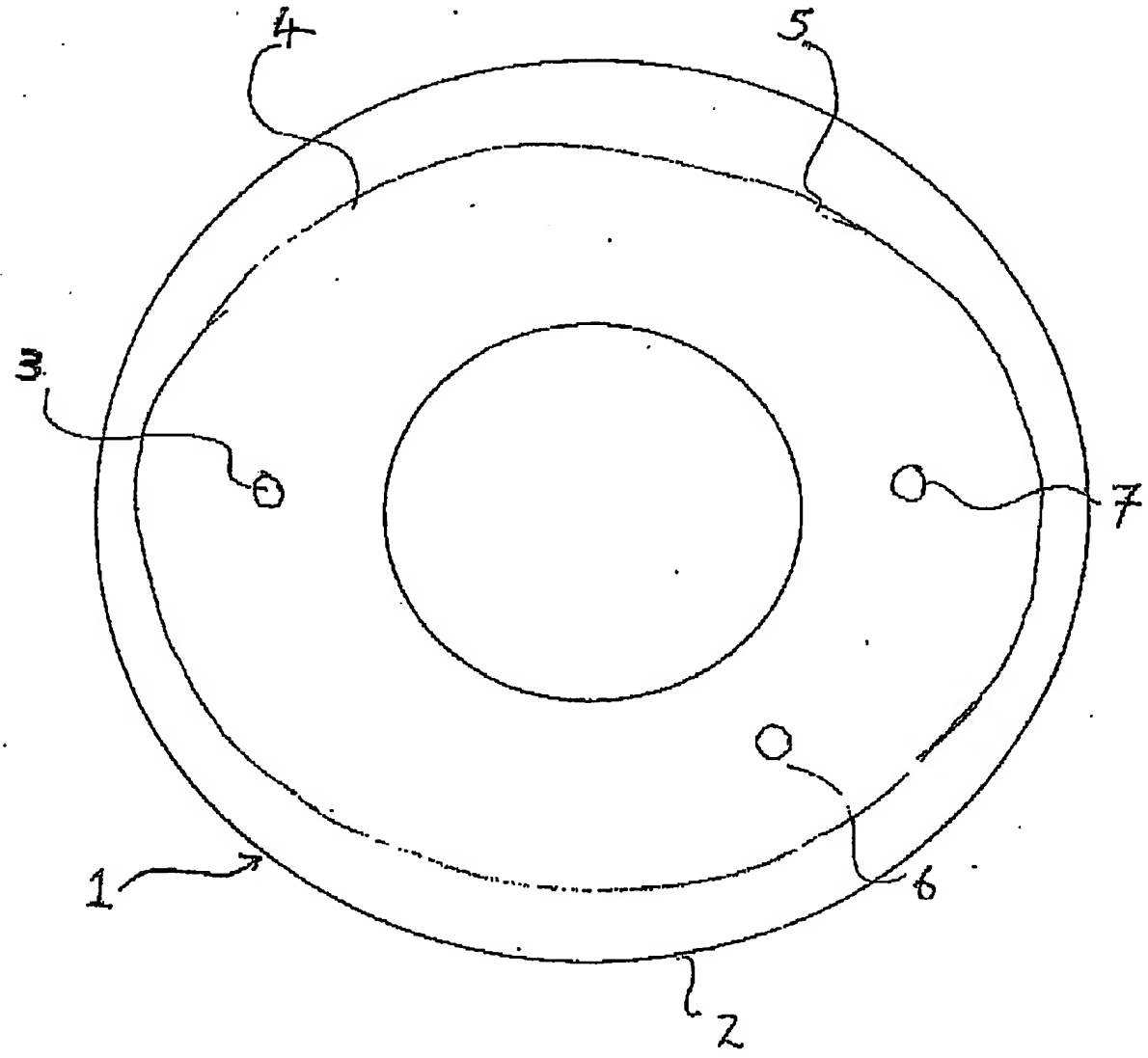

FIG. 1

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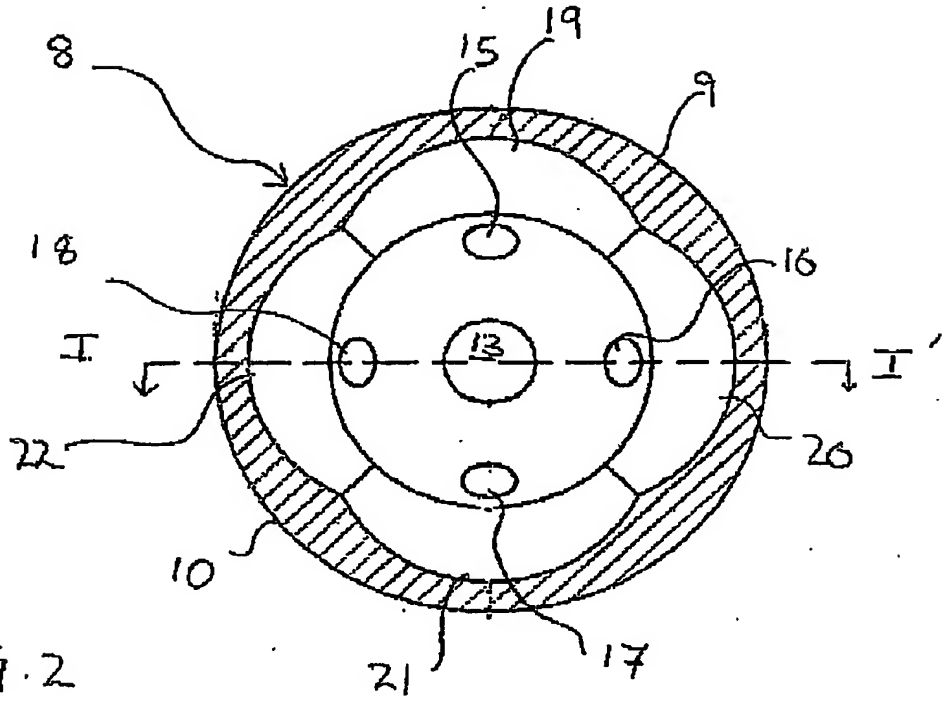


FIG. 2

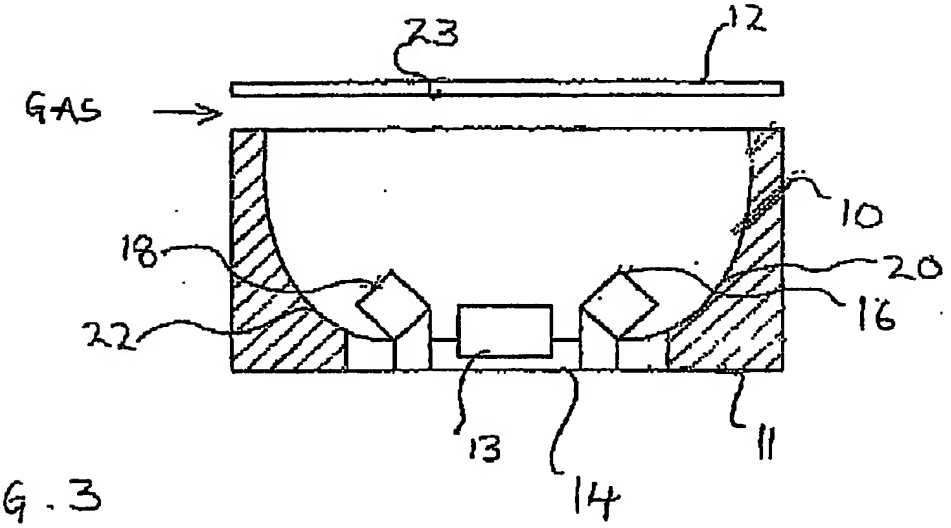


FIG. 3

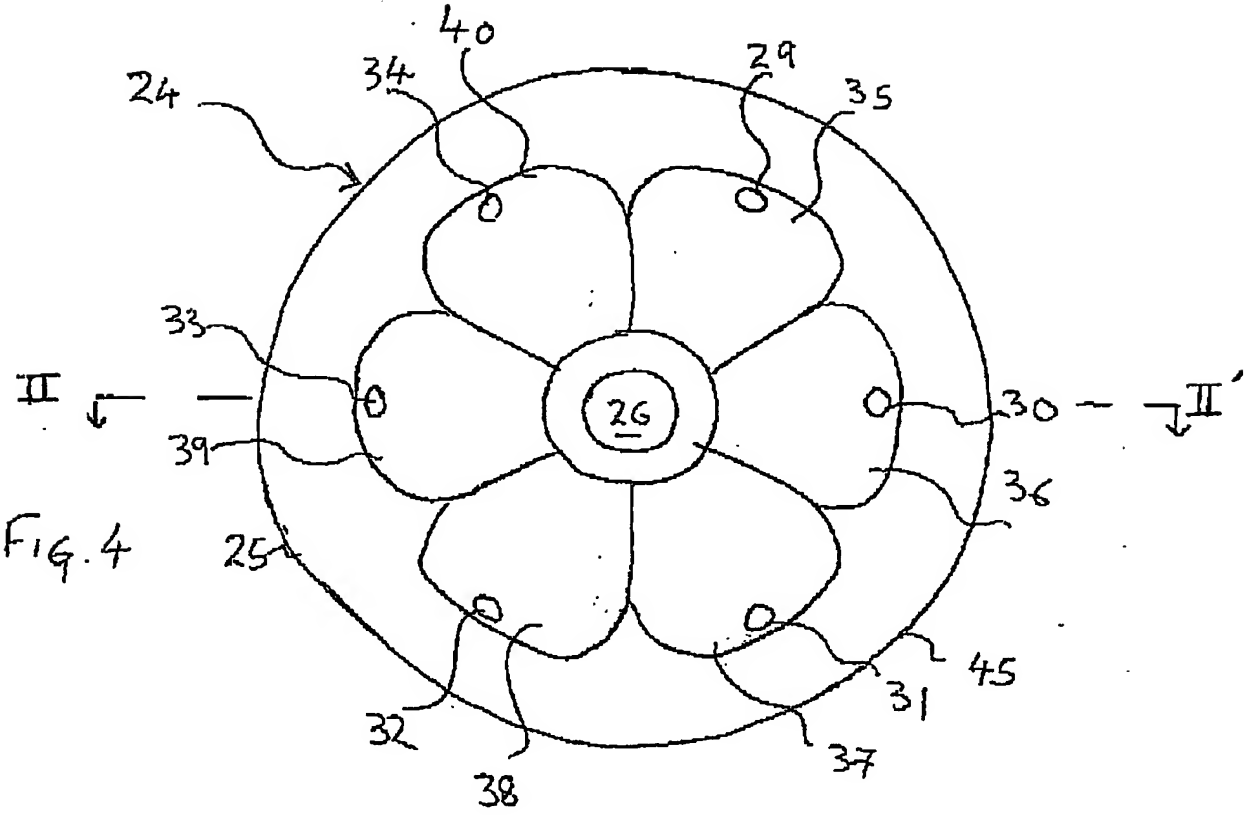


FIG. 4

FIG. 6a

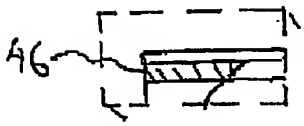
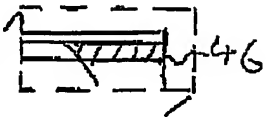


FIG. 6b



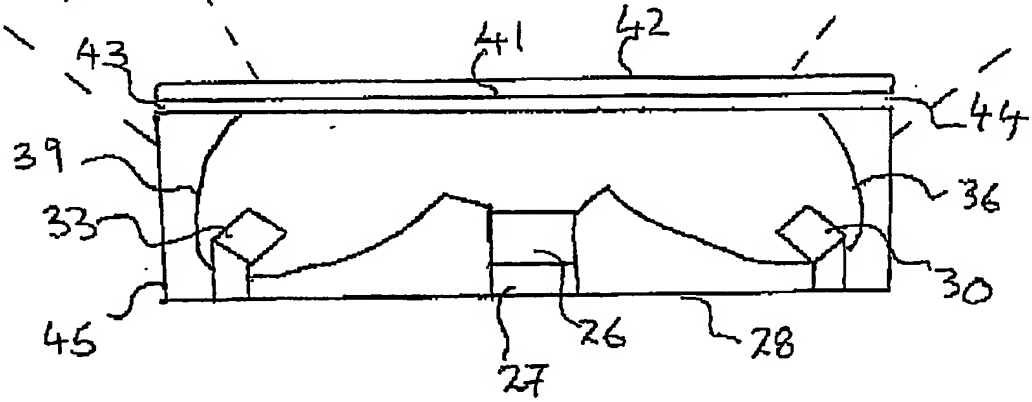


FIG. 5

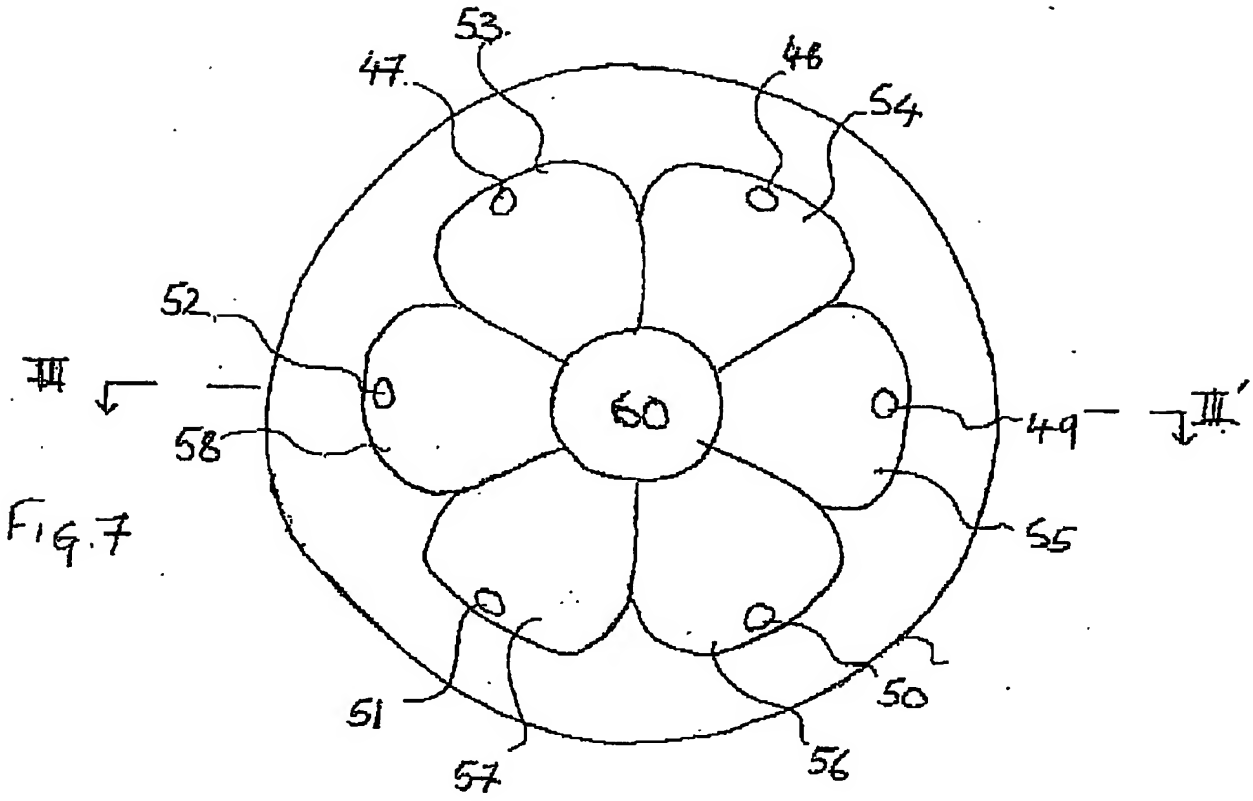


FIG.7

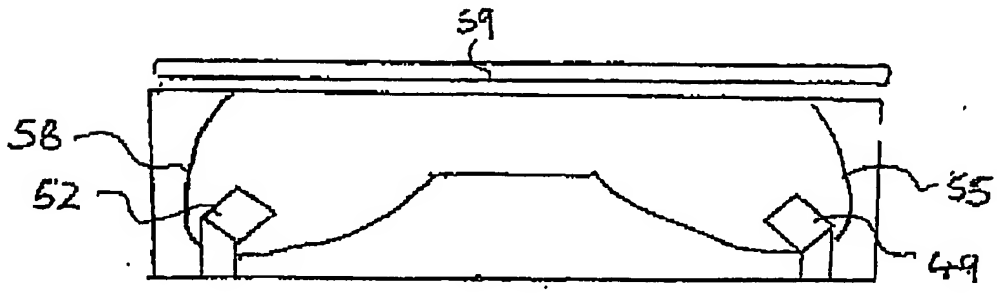


FIG.8

ABSTRACT

Figure 3

GAS SENSORS

A gas sensor of the type having a housing defining a chamber within which light is transmitted from a source to a detector through an optical path, includes internal mirror portions having part ellipsoidal shape. Light is transmitted from a source to a detector via the reflective portions. The detector is arranged to sense light only from a limited range of angles, such that only light transmitted through a defined optical path reflected off the two reflective portions from the source reaches the sensor. This ensures that there is a constant optical path from the source to the detector, which improves the signal to noise ratio of the device.

DUPLICATE

GAS SENSORS

This invention relates to apparatus for, and methods of, sensing gasses. The invention particularly relates to such methods and devices in which optical radiation is transmitted through a gas and subsequently detected to provide information concerning the gas.

In a typical gas sensor, an infrared source is arranged to emit radiation, which passes through a gas to be sensed. Infrared radiation is absorbed by the gas and that remaining is subsequently detected by an infrared detector, such as a photodiode, thermopile or pyroelectric detector. A comparison is made between the source intensity and the intensity of radiation detected following passage through the gas to give the concentration of a target gas. The concentration is related to the intensity by the following equation:

$$I = I_0 e^{-\varepsilon c l}$$

where I is the intensity of radiation detected by the detector, I_0 is the intensity of radiation emitted at the source, c is effectively a constant which is dependent on the particular gas being monitored, c is the gas concentration and l is the distance travelled by the radiation through the gas.

The present invention seeks to provide a gas sensor having improved characteristics over those previously known.

The invention provides a gas sensor comprising a chamber arranged to admit gas, an optical source, a first detector means sensitive to light from the source and a second detector means sensitive to light from the source, wherein light from the source travels a first predetermined optical path to the first detector and a second predetermined optical path to the second detector.

The provision of a second detector permits two different target gasses to be identified. The detectors may be tuned to detect different gasses by the provision of, for example, bandpass filters.

The first and second optical paths may have the same or different lengths. Gasses having high IR absorption characteristics need only a short optical path to provide suitable concentration resolution. Gasses having low IR absorption characteristics require a relatively long optical path

Alternatively, the invention enables a target gas to be detected with greater certainty. If the gas is present in high concentrations, then only a short optical path is needed for detection. If the target gas is present in low concentrations, then a longer optical path is required in order to firmly identify the concentration of the gas in the sample.

Advantageously, the chamber includes reflective surfaces arranged to reflect light from the source into desired optical paths. The reflective surfaces may have a plurality of foci. The source and the sensors may be located substantially at respective

foci. Alternatively, the source may be mounted in a central position, with the detectors arranged around the source.

The reflective surfaces may comprise a plurality of ellipsoids. The source and sensors may be located at a focus of respective ellipsoids. Alternatively, the ellipsoids may be arranged around the central region, with only the detectors being located at the foci of the ellipsoids. In any case, the ellipsoids advantageously have a common virtual focus. The ellipsoids provide a folded optical path for radiation from the source. This feature ensures that the detectors receive light of similar intensities. Further detail on ellipsoidal reflectors may be found in our British patent No. 2316172.

Of course, further sensors may be provided, and the inner surfaces of the chamber may be configured to provide more reflectors that are part ellipsoidal for the sensors.

The optical source is preferably an infrared source but sources and sensors operating in other parts of the optical spectrum may be used in other embodiments.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of a gas detector constructed according to the invention;

Figure 2 is a plan view of an alternative gas sensor constructed according to the invention;

Figure 3 is a schematic sectional side view of the sensor of Figure 2 along the line I-I;

Figure 4 is a plan view of a further alternative gas sensor constructed according to the invention;

Figure 5 is a schematic sectional side view of the sensor of Figure 4 along the line II-II;

Figures 6a and 6b illustrate alternative embodiments of the gas admittance regions of the sensor of Figure 5;

Figure 7 is a plan view of a further alternative gas sensor constructed according to the invention; and

Figure 8 is a schematic sectional side view of the sensor of Figure 2 along the line III-III.

With reference to Figure 1, a gas sensor constructed according to the invention is shown and indicated generally by the reference numeral 1. The detector 1 comprises a

housing 2, which is preferably flameproof, and which contains a source 3 of infrared radiation. Interior surfaces of the housing 2 are reflectors of infrared radiation.

The interior of the housing 2 includes two partially overlapping part ellipsoids 4,5. The source 3 is placed substantially at the focus of the first part ellipsoid 4. A first detector 6 is located in the chamber in a predetermined position such that a portion of light from the source 3 reaches the detector 6 via predetermined optical paths. This first sensor 6 may be arranged to detect gasses having high IR absorption coefficients, as the optical path length between this sensor and the source 3 is relatively short.

In accordance with the invention, a second detector 7 is located at the focus of the second part ellipsoid 5. As seen in plan view, the second detector 7 is located opposite the source 3. The optical path length between the source 3 and this detector 7 is relatively long, compared with the optical path length between the source 3 and the first detector 6. Hence, this detector 7 may be suitable for detecting gasses having low IR absorption characteristics. The configuration of the interior reflective surfaces of the housing 2 and locations of the source 3 and detectors 6, 7 are such that infrared radiation emitted from the source 3 is travels predetermined optical paths to the detectors 6, 7, via the part ellipsoidal surfaces 4, 5.

An alternative embodiment of the invention is illustrated in Figures 2 and 3. With reference to Figures 2 and 3, a gas sensor is shown and indicated generally by the reference numeral 8. The sensor 8 comprises a housing 9, which is preferably flameproof. The housing 9 comprises a generally cylindrical wall 10 with end walls 11

and 12. The housing 9 contains a source 13 of infrared radiation that, in this embodiment, is located approximately in a central region 14 of the end wall 11. The source is arranged to emit infrared radiation over a wide range of angles.

In accordance with the invention, the sensor 8 includes a plurality of infrared detectors 15, 16, 17 and 18. The detectors 15 to 18 inclusive are also mounted in the end wall 11 and are located at the foci of respective part-ellipsoids defined by curved walls 19, 20, 21 and 22 respectively. The curved walls 19 to 22 are arranged around the central region 14, so that the four ellipsoids are equally spaced around the inner circumference of the cylindrical housing 9. Thus, the arrangement of detectors 15 to 18 around the source 13 is substantially symmetrical as seen in the plan view of Figure 2, the detectors being equidistant from the source.

With reference to Figure 3, the reflective walls 20 and 22 associated with detectors 16 and 18 are shown. Each wall is curved in three dimensions to define a part ellipsoid. Detector 16 is located at a focus of the part ellipsoid defined by wall 20. Similarly, detector 18 is located at a focus of the part ellipsoid defined by wall 22. The end wall 12, opposite that on which the source 13 and detectors 15 to 18 are mounted, has a reflective inner surface 23, which is planar

The configuration of the reflective surfaces 19 to 23 and locations of the source 13 and detectors 15 to 18 are such that infrared radiation emitted from the source 13 is directed onto the planar surface 23, from which it is reflected and directed onto the part-ellipsoidal surfaces. Radiation is reflected by the reflective surfaces 19 to 22 to the

respective detectors 15 to 18, where the radiation is focussed. Thus, the radiation undergoes two reflections before being received at the detectors. In this embodiment, the optical path lengths of radiation travelling from the source 13 to the detectors 15 to 18 are substantially equal.

The ellipsoids defined by the surfaces having detectors at the focus are arranged to have a substantially common virtual focus.

A further alternative arrangement is shown in Figures 4 and 5. In this embodiment, a gas sensor 24 comprises a housing 25, in which is located a source 26 of infrared radiation. The source 26 is mounted in a central region 27 of a wall 28 of the sensor 24. Six detectors 29 to 34 are mounted in the wall 28. Each detector is equidistant from the source and the detectors are uniformly spaced around the interior of the cylindrical housing 25. Each detector 29 to 34 is associated with a part-ellipsoidal surface (35 to 40 respectively), and each detector is located at the focus of the ellipsoid defined by the surface.

Radiation emitted by the source 26 is reflected by a planar surface 41 associated with the upper wall 42 of the sensor. Radiation reflected by the surface 41 is directed towards the part-ellipsoidal surfaces 35 to 40, each of which directs radiation onto its respective detector. Radiation is directed from the source to each detector via distinct predetermined optical paths.

The provision of a plurality of detectors permits a plurality of gasses to be detected. The detectors may incorporate bandpass filters having different or overlapping frequency bands in order to facilitate the detection of target gasses.

It is preferable to be able to allow gas to pass in and out of the housing as quickly as possible, to increase the likelihood of a positive and rapid identification of the target gas, and a measure of its concentration. In the embodiment shown in Figures 4 and 5, an inlet port 43 and an outlet port 44 are provided, through which gas may be directed to pass into the housing 25. The ports 43, 44 are embedded in diametrically opposite sides of the cylindrical wall 45.

Figures 6a and 6b illustrate alternative gas admittance means. In this arrangement, regions 46 of the cylindrical wall 45 not providing reflective surfaces for the light may include particulate filters, mesh or sintered material.

In the above embodiments, a solitary source is employed. However, in the embodiment of Figures 7 and 8, a plurality of sources 47, 48, 49 are incorporated in the gas sensor. Each source 47, 48, 49 is associated with a detector 50, 51, 52 respectively. Each detector 50, 51, 52 is mounted diametrically opposite its source. Each of the sources and detectors are located at the foci of respective part-ellipsoidal reflective surfaces 53 to 58. Light emitted by each source is reflected by the associated part-ellipsoidal surface, and is also reflected by the planar surface 59 associated with the upper wall of the housing and a central reflective surface 60.

The housing may include a reference detector for compensating for changes in operating conditions and with time. The reference detector includes a different filter to those fitted in the active detectors and does not respond to the target gas. By comparing the signals from at least one of the active detectors and the reference detector, the user can discriminate the signal reduction due to the target gas from that due to ambient and physical variations. The reference detector is preferably located immediately adjacent an active detector so that the detector and reference collect radiation that has travelled similar optical paths. To aid this, the reference detector may be contained in a single detector package with an active detector.

A suitable infrared source is a wide-angle tungsten lamp, which provides a broadband infrared thermal source. Other sources include LEDs, lasers or diodes with lenses, especially immersion lenses. A diffuser may be placed over the infrared source in order to reduce filament imaging effects. This also improves the thermal stability of the gas sensor and also renders the device less sensitive to movements of the filament.

In order to reduce the amount of stray light within the gas sensor, reflective barriers or collimators may be provided around the source of infrared radiation and/or the detectors.

A diffuser may also be placed over one or more of the detectors in order to reduce reflective cusps or imaging effects. This further improves the thermal stability of the gas sensor and gives greater immunity to localised changes in reflectance.

The reflective surfaces may comprise layers of plated gold to provide good reflectance. At least some of the reflective areas may comprise coatings of a matt gold finish. The provision of matt gold further reduces reflective cusps or imaging effects, as well as further improving the thermal stability of the gas sensor and giving greater immunity to localised changes in reflectance.

The length of the optical path through the chamber may be altered by adjusting the relative positions of the sensors and source. Further alterations in optical path length may be achievable by adjusting the separation between the planar reflective surfaces. Alternatively, or additionally, the dimensions of the inner surfaces of the chamber may be changed so that the ellipsoids they represent are of different sizes or have a different angular separation.

The chamber may be a single component or may comprise a plurality of pieces. A suitable manufacturing process for the contours of the chamber is that of machine turning. Alternatively, moulding in plastics or metal injection may be utilised. These processes are well known industrial techniques and may be readily employed by the skilled person.

The invention may be used in conjunction with directional sensors and sources, as described in our co-pending patent application, given the reference P/63665/VISD in the records of our Patent Department.

CLAIMS

1. A gas sensor comprising a chamber arranged to admit gas, an optical source, a first detector means sensitive to light from the source and a second detector means sensitive to light from the source, wherein light from the source travels a first predetermined optical path to the first detector and a second predetermined optical path to the second detector.

2. A sensor as claimed in claim 1, wherein the length of the first optical path is substantially equal to the length of the second optical path.

3. A sensor as claimed in claim 1, wherein the length of the first optical path is different from the length of the second optical path.

4. A sensor as claimed in claim 1 or 2, further comprising reflector means having reflective surfaces in the chamber.

5. A sensor as claimed in claim 4, wherein the source is located substantially at a first focus of the reflector means.

6. A sensor as claimed in claim 4, wherein the first detector is located substantially at a second focus of the reflector means.

7. A sensor as claimed in any one of claims 4 to 6, wherein the source is at a focus of a first part ellipsoidal surface, the first detector is at a focus of a second part ellipsoidal surface and the first and second ellipsoids share a common virtual focus.

8. A sensor as claimed in any one of claims 4 to 7, wherein the source and the first detector are diametrically opposite each other.

9. A sensor as claimed in claim 8, further comprising a second source diametrically opposite the second detector.

10. A sensor as claimed in claim 4, wherein the first detector is located substantially at a first focus of the reflector means.

11. A sensor as claimed in claim 10, wherein the second detector is located substantially at a second focus of the reflector means.

12. A sensor as claimed in claim 10 or 11, further comprising a central region between the first and second foci, the source being located in the central region.

13. A sensor as claimed in claim 10, 11 or 12, wherein the first detector is at a focus of a first part ellipsoidal surface, the second detector is at a focus of a second part ellipsoidal surface and the first and second ellipsoids share a common virtual focus

14. A sensor as claimed in claim 13, further comprising a third detector at a focus of a third part ellipsoidal surface sharing a common virtual focus with the first and second ellipsoids.

15. A sensor as claimed in claim 14, further comprising a fourth detector at a focus of a fourth part ellipsoidal surface sharing a common virtual focus with the first, second and third ellipsoids.

16. A detector as claimed in any preceding claim, wherein the first sensor is arranged to detect a first predetermined gas and the second sensor is arranged to detect a second predetermined gas.

17. A detector as claimed in any preceding claim, further comprising a reference detector.

18. A detector as claimed in any preceding claim wherein the source and the sensors are contained within a flameproof housing.

19. A detector as claimed in any preceding claim wherein the optical source is an infrared source.

20. A detector as claimed in any preceding claim wherein the source is arranged to heat substantially all the surfaces from which light is reflected to a temperature above ambient temperature.

21. A gas detector, substantially as hereinbefore described, with reference to, or as illustrated in, the accompanying drawings.

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